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A FEASIBILITY STUDY FOR THE LABORATORY REDUCTION OF LOW LEVEL RADIOACTIVE WASTES

THEODORE J. KOPPENAAL
KOPPENAAL & ASSOCIATES
21095 WHITEBARK
MISSION VIEJO, CA 92692

JOSEPH A. FABIANO
ARDEC
PROJECT ENGINEER

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A FEASIBILITY STUDY FOR THE LABORATORY REDUCTION OF LOW LEVEL RADIOACTIVE WASTES

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Theodore J. Koppenaal, Koppenaal & Associates and Joseph A. Fabiano, ARDEC, Proj Engr

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16. SUPPLEMENTARY NOTATION
Reducing the cost of disposing of and the volume of low level radioactive wastes using a small research laboratory system under appropriate safety, health, physics, and regulatory requirements is feasible.

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FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (CONTINUE ON REVERSE IF NECESSARY AND IDENTIFY BY BLOCK NUMBER)
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19. ABSTRACT (CONTINUE ON REVERSE IF NECESSARY AND IDENTIFY BY BLOCK NUMBER)

Results of the literature search and analysis show it is technically feasible to ash (20:1-50:1), evaporate (100:1), and completely passivate (convert metallic uranium to uranium oxide) low level radioactive wastes (LLRW) contaminated with depleted uranium or tritium using a customized conventional type muffle furnace. The slow-burn ashing, evaporation, passivation, shearing, compacting approach is a low cost, safe, reliable, volume reduction procedure for handling the expected volume of LLRW generated at ARDEC.

Ashing passivation of rubber, plastics, leathers, and ion exchange resins was not recommended because of the toxic products of combustion with these materials. Volume reduction (5:1) of these low level radioactive nonashable materials and filters requires specially engineered compactors.

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18. SUBJECT TERMS: (cont)

Laboratory type muffle furnace, Depleted uranium contaminated low level waste, Tritium contaminated low level waste

CONTENTS

1.0 INTRODUCTION

1.1 Background

Depleted uranium manufacturing operations generate various types of wastes that are contaminated with the uranium, and this necessitates special packaging, storage, transportation and disposal procedures. For those wastes that are combustible, slow burn ashing-passivation produces a very significant volume-weight reduction. This volume-weight reduction is an important factor since burial costs are becoming a significant portion of any depleted uranium manufacturing operation. In addition to being cost effective, slow burn ashing-passivation converts the wastes to a safer form for both storage and transportation. Slow burn ashing-passivation is also one of the few disposal procedures that meets the restrictions of available burial sites. For those low level wastes that can not be ashed-passivated, compaction can be used to significantly reduce their volume.

ARDEC generates small amounts of research and development wastes contaminated with depleted uranium and some wastes contaminated with tritium. As a result, there is a need to volume-weight reduce these wastes by ashing-passivation, and it would be desirable to perform these operations with a small laboratory system.

1.2 Objectives

The objective of this program was to determine the feasibility of reducing the volume of dry, low level radioactive wastes by either

ashing-complete passivation, compaction or other viable alternatives using a small laboratory system. The wastes being considered are contaminated with tritium and depleted uranium (which may be in the form of machine chips, saw fines, grinding sludge, fragements, particulates, dust and other unspecified shapes) and include a variety of contaminated laboratory research and development wastes such as paper, wood, cloth (cotton), toluene, pseudocumene, and other chemicals used in ARDEC radiation processes, HEPA filters, plastic, leather, and ion-exchange resins. The feasibility of using a conventional, muffle type furnace for accomplishing the ashing-passivation was included in the objectives. In addition, another objective of the feasibility study was to insure that the ashing-passivation and/or compaction could be done under appropriate safety, health physics and regulatory requirements.

1.3 Approach

The major effort of the program involved a literature search to determine one, the feasibility of ashing-passivation low level radioactive wastes in a standard muffle furnace, and two, to determine the expected volume reduction of low level radioactive wastes following complete passivation or compaction. Several other factors related to the overall feasibility study were evaluated as part of the program.

The results of the literature search are given in Section 2, and various critical design parameters and other factors are presented in Section 3. The conclusions and recommendations are given in Section 4.

2.0 LITERATURE SURVEY

2.1 Literature Search

A literature search was conducted on the ashing-passivation, compaction and volume reduction of low level radioactive wastes using DIALOG. The National Technical Information Service (NTIS), Chemical Abstracts and METADEX files were used for the search. Based upon these searches, a total of twenty-nine papers/reports were identified and reviewed. Since the Chemical Abstracts search does not provide an abstract (only identifier words are given), some of the reports that were ordered did not directly relate to the task of this investigation.

A bibliography of the references obtained as part of this study is given in the Appendix at the end of this report. A short abstract of each report is also given.

2.2 Slow Burn Ashing-Passivation of Low Level Depleted Uranium and Tritium Comtaminated Radioactive Wastes

The most important factor established by the literature search was that no previous account was found where the ashing-passivation of low level, radioactive wastes was done in a conventional muffle-type furnace. In a report by Brown, et al.[4], a laboratory-scale prototype furnace was used under controlled ashing conditions, but this was especially designed for that procedure. This study indicated that there wasn't anything basically prohibitive about using a laboratory scale furnace for the reduction.

The literature search did establish that several different passivation procedures are being used for the volume-weight reduction of low level

radioactive wastes. Different approaches based upon ashing included controlled air ashing, rotary kiln ashing, agitated hearth ashing, fluidizied bed ashing, vortex ashing and cyclone ashing; in addition, non-ashing procedures such as molten salt combustion and acid digestion are also being used for reducing the volume of radioactive wastes.

While the literature search did establish several different passivation procedures, there are some similarities in these approaches that related to the present study. Nearly all of systems were based upon a dual chamber concept where the radioactive wastes were first pyrolyzed in one chamber and then completely passivated in a second chamber. The amount of secondary fuel required for the first chamber was minimal since most radioactive wastes are highly exothermic during ashing; in the second chamber, however, the fuel supply (or electrical resistance heating) provided virtually all the heat required to maintain the desired temperatures. The temperature of the first chamber varied from about 1100 to 1500 degrees F and the second chamber varied from about 1650 to 2000 degrees F.

Another similarity of the passivation systems was in the treatment of the off-gas. In addition to HEPA filters, all of the fully developed systems used some type of scrubber in the exhaust system to remove substances like Cl_2, SO_3, HCl, NH_4, NO_x and HCN that are produced from ashing materials such as plastics and leather. One of the systems (see the reports from the Los Alamos National Laboratory), pass the off-gases through a quench column, venturi scrubber, packed column, condenser, de-mister, re-heater, HEPA filter and carbon bed adsorber prior to exhausting.

For the complete passivation of metallic uranium manufacturing wastes, experience with systems similar to those described above has shown that over 99% of the uranium is converted to uranium oxide.

2.3 Volume-Weight Reduction of Low-Level Depleted Uranium and Tritium Contaminated Wastes Following Ashing and Complete Passivation

Specific volume reductions of low level radioactive wastes following complete passivation were given by a number of authors, and their results are shown below in Table I.

Table 1

Volume-Mass Reduction of Low Level Wastes After Complete Slow Burn Ashing-Passivation-Shearing-Compaction of Depleted Uranium and Tritium Contaminated Wastes

Reference	Volume Reduction	Weight Reduction
Bond, et al.[1]	38:1	9:1
Brown, et al.[4]	20:1	
Campbell[5]	35:1	
Laser[14]	20:1 to 80:1*	
Luthy, et al.[15]	50:1	20:1
Meile, et al.[17]	25:1	5:1
Ohtsuka, et al.[18]	50:1 to 100:1**	
Treat, et al.[25]	22:1	
Van de Voorde, et al.[26]		18:1
Vavruska, et al.[27]	125:1	30:1 to 40:1

* the 80:1 reduction obtained with Supercompactors

** for HEPA filters only

In general, volume reductions of about 20:1 to 50:1 have been obtained. Most of the variations between these studies can be accounted for by either considering the manner in defining the volume prior to ashing, the materials being passivated (sometimes non-combustibles were included), compaction after passivation or by the ashing-passivation procedure itself (primarily the highest temperature).

2.4 Time-Temperature-Volume Relationships

Very few of the reports dealing with the volume reduction of radioactive wastes after ashing or passivation gave any information concerning the time-temperature-volume relationships. In addition, most of the systems reported upon were not of the type being evaluated here (most involved continuous feed systems with daily capacities of several hundred pounds or more). As a result, only a limited amount of data was found that is applicable to the present evaluation. It is, therefore, suggested that any laboratory study include procedures to measure the time-temperature-volume relationships.

Luthy, et al.[15] reported that 200 to 500 lb. charges of wastes could be ashed in 4 to 8 hours with a 50:1 volume reduction (and 20:1 weight reduction). Unfortunately, the ashing temperature(s) was not given. This time period appears to be somewhat typical for most of the other types of systems as well (large capacity, continuous feed).

Bond, et al.[1] found that after the first stage of ashing, the carbon content of the ash was about 20%. After an additional one hour at about 1475 deg F, the carbon content was reduced to .04%.

2.5 Compaction

Compaction has been used for some several years to reduce the volume of many types of radioactive wastes. In a 1977 repc . Clark, et al.[6] states that compressible wastes can be volume reduced 70-80% (about a 4:1 to 5:1 ratio) using relatively inexpensive equipment.

Various types and sizes of presses are available for compaction depending upon the specific need. Compactors with a press capacity of about 10-12 tons are used to compress dry paper, cloth, plastic, gloves, etc. into 55-gallon drums with volume reductions of about 5:1.

Twenty-five ton press compactors are available with chamber sizes large enough to contain standard 2'x2'x1' HEPA filters and other dry trash for compaction into small bales. Compacting HEPA filters in this manner also produces about a 5:1 volume reduction, and other dry wastes compacted with these larger presses give higher volume reductions. The bales can be packaged in metal shipping boxes with other compactible or non compactible waste for burial (see 3.8). In addition, compactors can be used to compact wood frame HEPA filters directly into 85-gallon drums. The potential pyrophoric characteristics of embedded depleted uranium fragments and particulates has been of major concern in the HEPA filters used to clear the target-impact area of airborne contaminants after firings of depleted uranium projectiles. Cases of spontaneous ignitions in the depleted uranium loaded HEPA filters have been reported, and this raises the concern about insuring the complete passivation of spent filters prior to disposal. To passivate depleted uranium loaded HEPA filters, either the entire filter can be passivated (for wood frame filters) or the filter element can be sheared from the frame (of metal frame filters) and passivated.

Fifty to seventy-five ton press compactors are made to compact inside large (100 cubic feet) metal shipping containers. These compactors can be used to compress HEPA filters and other types of dry wastes.

Laser[14] notes that compared with conventional presses, supercompactors of 5000 to 7000 tons give an additional volume reduction factor of about 2.

Compactors used with low level radioactive wastes are generally equipped with a HEPA filtered ventilation system to control airborne emissions.

2.6 Safety, Health Physics and Regulatory Requirements

The report by Taylor, et al.[24] is a guide for the disposal of radioactive materials, and it covers several phases of the disposition including approvals, packaging and shipment.

Recommended practices for radiation protection from low level radioactive materials are given by Hadlock, et al.[9]. An ALARA (as low as reasonable achievable) Program is described and covers ALARA policy, program responsibility and authority, training, facility and equipment design, procedures, controls, preplanning and program effectiveness.

3.0 CRITICAL DESIGN PARAMETERS AND OTHER FACTORS

Since the literature survey failed to identify any prior reports of ashing-passivation in conventional muffle furnaces, various parameters were evaluated that are of critical importance to the operation of an ashing-passivation system based upon this approach. For these evaluations, we will assume ashing-passivation in some type of muffle furnace with a hearth size of about four cubic feet, a maximum batch load capacity of one cubic foot and some type of venting around the furnace that exhausts into a laboratory hood. The goal of this section is to determine if the general ashing-passivation approach appears to be technically feasible.

3.1 Air Requirements for the Ashing of Wood

In this section, the amount of air required to completely passivate one cubic foot of wood is determined, and an evaluation is made about the feasibility of suppling this amount of air with the type of furnace being considered.

Using 30 lbs/ft^3 as the density of wood (Douglas Fir) and assuming that wood is 1/3 water and 2/3 combustible material, the weight of the combustible material in one cubic foot of wood is,

$$1\ ft^3 \times 30\ lbs/ft^3 \times 2/3 = 20\ lbs.\ \text{combustible material.} \qquad (1)$$

The primary reaction during ashing is,

$$C + O_2 \longrightarrow CO_2. \qquad (2)$$

Since air is 20% oxygen, the amount of air required is,

$$20\ lbs \times \frac{2 \times 16}{12} \times \frac{1}{.2} = 268\ lbs. \qquad (3)$$

With the density of air being .0743 lbs/ft^3, the total volume of air required becomes,

$$\frac{268 \text{ lbs}}{.0743 \text{ lbs/ft}^3} = 3{,}600 \text{ ft}^3 \text{ of air.} \quad (4)$$

If the ashing is done evenly over a twenty hour period, the air requirement to ash one cubic foot of wood is,

$$\frac{3{,}600 \text{ ft}^3}{1{,}200 \text{ min}} = 3.0 \text{ ft}^3/\text{min.} \quad (5)$$

Thus, the furnace would have to have air inlets and outlets such that 3 CFM can enter the ashing chamber and eventually be vented into a laboratory hood. This does not appear to be a problem with the type of equipment being evaluated. Small vents in the furnace could provide this amount of air exchange without any significant problems. Alternatively, a small 3 CFM fan and motor could be installed to draw this amount of air through the furnace. Another alternative is to open the furnace to allow sufficient air inside, and recycle the same load to assure the maximum ashing of the load and complete passivation of depleted uranium and/or tritium.

3.2 Heat Generation During the Ashing of Wood

The amount of heat generated by the ashing of one cubic foot of wood over a twenty hour period is presented in this section, and the effect of that amount of heat to the furnace and exhaust system is evaluated.

The amount of heat generated by the ashing of one cubic foot of wood is 163,000 BTU (Handbook of Physics and Chemistry). If we assume that all this heat goes into the exhaust system over a twenty hour period, the average temperature increase, ΔT, of the air due to this heat would be (using .24 BTU/lb/F as the specific heat of air),

$$\Delta T = \frac{163{,}000 \text{ BTU}}{268 \text{ lbs} \times .24 \text{ BTU/lb/ F}} = 2530 \text{ F.} \quad (6)$$

If ambient air is about 70 degrees F, the temperature of the air in the furnace would be,

$$70 + 2530 = 2600 \text{ deg F.} \quad (7)$$

The actual temoerature will be somewhat less than this due to various heat losses including heating the various furnace materials.

While the inside of the furnace could basically withstand this general temperature range (although some modification to specific components such as the heating elements might be required), the exhaust system for the laboratory hood would be endangered since the HEPA filters that provide containmert of radioactive particles lose their filtering capability at temperatures of about 1000 degrees F (for some high temperature HEPA filters). Therefore, the exhaust gases must be diluted with ambient air to provide necessary amount of cooling.

If the maximum temperature in the exhaust hood is to be kept to a temperature of 270 degrees F maximum (a ΔT of 200 deg F), the necessary ambient air flow is,

$$\text{air flow} = \frac{163{,}000 \text{ BTU}}{.24 \text{ BTU/lb/deg F} \times .0743 \text{ lb/ft}^3 \times 1200 \text{ min} \times 200 \text{ deg F}}$$

$$= 38 \text{ ft}^3/\text{min} \quad (8)$$

Since the rate of ashing is usually not constant, an air flow of about 100 CFM would safely provide the necessary cooling. Note that this air flow is into the laboratory hood (and not necessarily in the furnace

venting system). Since this air flow probably exists for most laboratory hoods, the heat generated by the ashing of one cubic foot of wood over a twenty hour period can be dissipated satisfactorily.

3.3 Air Requirements for the Ashing-Passivation of Uranium

In addition to using the furnace to ash low level R&D wastes, the furnace could also be used for the ashing-passivation of metallic uranium manufacturing wastes. In this section, the air requirements for thi passivation is examined.

The ashing-passivation of uranium proceeds by the reaction,

$$3U + 4O_2 \longrightarrow U_3O_8 \qquad \Delta H = 1817 \text{ BTU/lb.} \tag{9}$$

Using the density of air as .0743 lbs/ft^3 (at room temperature), the air requirement is,

$$\frac{8 \times 16}{3 \times 238} \times \frac{1}{.2} \times \frac{1}{.0743} = 12.05 \text{ ft}^3. \tag{10}$$

Therefore, about 12 ft^3 of air at room temperature are required for the complete passivation of one lb. of uranium. Since our previous calculation for wood sized the air flow at 3 ft^3/min, any furnace meeting that criteria could passivate about one lb. of uranium every four minutes (or, .25 lbs/min).

3.4 Heat Generation for the Ashing-Passivation of Uranium

Along with the air requirements for uranium ashing-passivation, the heat generated by the ashing also needs to be evaluated.

The previous section showed that the conversion of uranium to uranium oxide (U_3O_8) releases 1817 BTU/lb of heat and that there will be enough air supply to ash about .25 lbs of uranium per minute. Therefore, the heat input during the ashing is,

$$.25 \text{ lbs/min} \times 1817 \text{ BTU/lb} = 450 \text{ BTU/min.} \quad (11)$$

From section 3.2, the ashing of one cubic foot of wood over an twenty hour period releases,

$$\frac{163{,}000 \text{ BTU}}{1200 \text{ min}} = 136 \text{ BTU/min.} \quad (12)$$

Therefore, the ashing of uranium would release about 3.3 times more heat into the system than for wood. Since the system has already been sized for wood, the result of this analysis shows that either the air flow needs to be restricted to about 1 CFM when ashing uranium or the amount of uranium being ashed needs to be limited to 5 to 10 lb batches. Either (or both) of these approaches could be used without introducing any significant problems.

3.5 Radioactivity of Exhaust Effluents

In this section, the amount of radioactivity of the the exhaust effluents is presented, and the significance is evaluated.

If the maximum amount of uranium ashed in a given day is ten pounds, the amount of uranium leaving the furnace (and entering the laboratory exhaust hood) would be,

$$10 \text{ lbs} \times .0001 \text{ (escape factor)} = .001 \text{ lbs/day.} \quad (13)$$

The escape factor is defined as the amount of uranium that becomes airborne and leaves the ashing container; the value of .0001 is based upon years of empirical data obtained with uranium ashing systems.

With a HEPA filter in the exhaust hood (99.97% filtering efficiency), the amount of uranium leaving the HEPA filter would be,

$$.001 \text{ lbs/day} \times .0003 \text{ (escape factor)} = 3 \times 10^{-7} \text{ lbs/day.} \qquad (14)$$

Assuming an air flow of 100 CPM and using a value of .36 μCi/gm for the specific activity of depleted uranium, the maximum level of radioactivity associated with exhaust effluent is,

$$3 \times 10^{-7} \text{ lbs/day} \times 454 \text{ gms/lb} \times .36 \ \mu\text{Ci/gm} \times 1.0 \times 10^{-2} \text{ min/ft}^3 \times$$

$$6.94 \times 10^{-4} \text{ day/min} \times 3.53 \times 10^{-5} \text{ ft}^3\text{/ml} = 1.20 \times 10^{-14} \ \mu\text{Ci/ml.} \qquad (15)$$

This value is over 100 times lower than the DOE guideline of 2×10^{-12} μCi/ml, see DOE Order 5480.1, Attachment XI-1, Table II. Recall that this calculation is based upon the ashing of 10 lbs. of uranium, which would be unusually high; for a typical daily amount of .1 to 1 pound, the radioactivity of the exhaust effluent would be about 1,000 to 10,000 less than the DOE guideline. In practical terms, it will not be possible to detect uranium in the exhaust effluents, as these small amounts are not measurable.

Since tritium contaminated wastes are to be ashed, the radioactivity of the tritium also needs to be considered. Using the type of relationship given by eqn. (15) above, the allowable amount of tritium that can be ashed per day is about .59 milli-curies without exceeding the DOE guideline of 2×10^{-7} μCi/ml. Note that the .59 milli-curies represents an average daily amount; if ashing of tritium contaminated wastes is only done once a week, for example, then about 3 milli-curies could be ashed.

3.6 Products of Combustion

Considering that the planned approach is to use a muffle furnace with only HEPA filters in the off-gas system, the products of combustion for the various types of radioactive wastes become important in considering the feasibility of the approach. The products of combustion in ample air for each material under consideration have been determined, and they are shown in Table II on the following page.

In view of the considerations shown in the table and the desired use of a muffle furnace with just a HEPA filter for the off-gas (no scrubbers), only the slow burn ashing-passivation of depleted uranium, wood, paper, cloth (cotton), toluene, pseudocumene and HEPA filters are being recommended. The nature of the off-gases from leather, plastics and ion-exchange resins prevents them from being considered for ashing without some type of scrubber.

3.7 Metallic Uranium Analysis

The experimental technique used to determine the amount of metallic uranium in a mixture of uranium metal and oxides is based upon immersing a sample in hydrochloric acid and measuring the volume of hydrogen gas evolution due to the reaction with metallic uranium.

3.7.1 Experimental Procedure

A. Clean sample in MEK to remove oil residue.

B. Rinse sample in water and dry.

C. Weigh a sample of .5 to .6 grams to at least three significant figures.

D. Place weighed sample in a 10-ml beaker.

Table 2

Products of Combustion

Material	Product(s) of Combustion	Consideration(s)
Uranium	U_3O_8 (solid)	Radioactive
Tritium	Tritium Oxide (heavy water)	Very weak beta
Wood, Paper & Cloth (cotton)	CO_2, H_2O, SO_3, NH_4, HCN and ash	Very small amounts of SO_3, NH_4 & HCN
Leather	CO_2, H_2O, NO_x, HCl, Cl_2, HCN, H_2, SO_3, & carbon black	Most are toxic
Plastics (mixed)	CO_2, H_2O, CO, $COCl_2$, HCl, NO_x, Cl_2, SO_3, tars & smoke	Toxic
Toluene	CO_2, H_2O, CO, & carbon-black	Vent & filter
Pseudocumene, C_9H_{12}	CO_2 and H_2O	None
Ion-Exchange Resins	CO_2, H_2O, H_2S, H_2SO_4, HCl HCN, Cl_2, NO_x & SO_3	Toxic

E. Place the 10-ml beaker in a reaction flask containing about 50-ml of 6 mol HCl (a 1:1 solution of HCl and H_2O).

F. Connect the flask to an apparatus for measuring gas evolution (see Figure 1), open stopcock to atmosphere and adjust level of bulb to line-up meniscuses. Record burette reading.

G. Close top burette stopcock to atmosphere.

H. Shake reaction flask until sample mixes thoroughly with HCl.

I. Collect evolved gas for about 20 minutes or until reaction has ceased.

J. Take final burette reading and record.

3.7.2 Calculations

K. Note and record temperature in degrees K (=deg C + 273).

L. Note and record barometer reading in mm of Hg.

M. Determine (from a handbook) and record the vapor pressure of water at the temperature recorded in 3.7.2K above.

N. Calculate percentage of metallic uranium as follows:

$$\%U = \frac{(\text{ml gas evolution})\ (A)\ (B)\ (100)}{\text{sample weight in grams}} ,$$

where A = .00608 gms, a factor used for converting ml H_2 gas at STP to gms of uranium, and

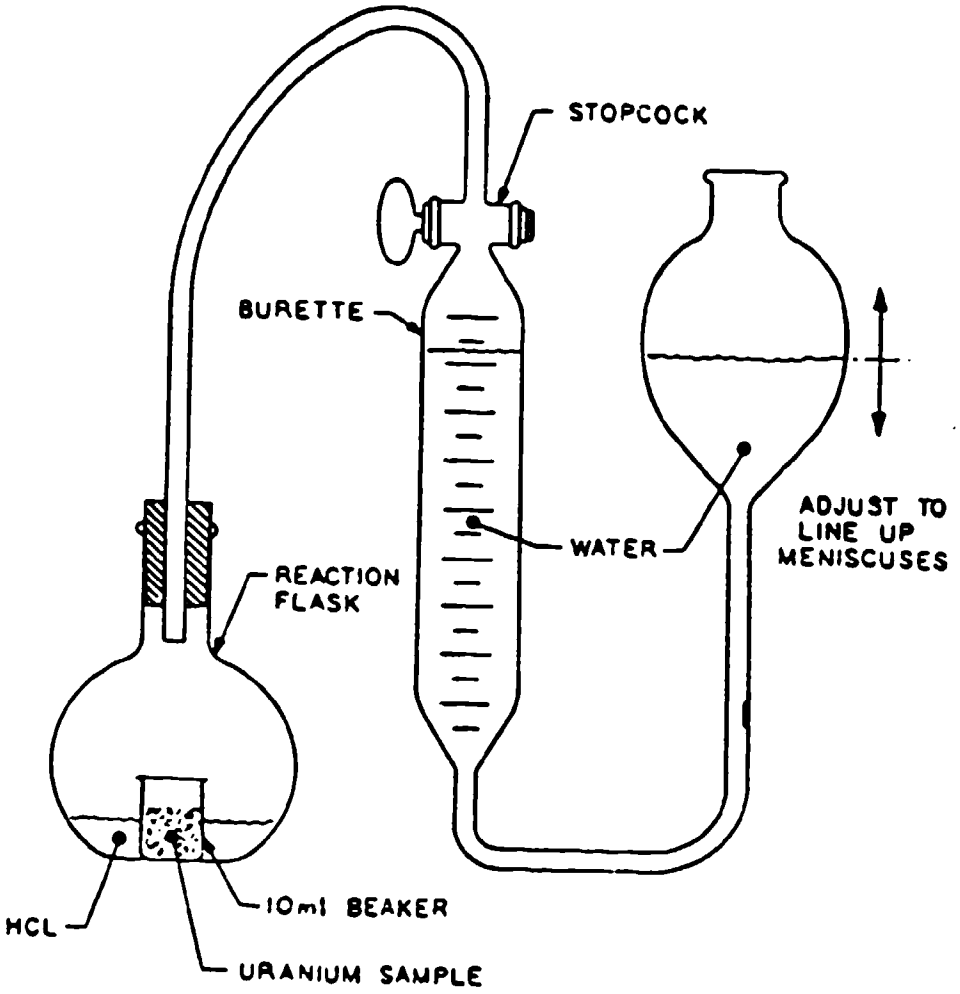

Figure 1 Experimental Set-Up For Measuring Amount Of Metallic Uranium Present.

$$B = \frac{(\text{barometric pressure} - \text{vapor pressure } H_2O)(273)}{(760)\ (\text{deg K})}$$

3.7.3 Sample Calculation:

21.2 deg C = temperature
756.4 mm Hg = barometric pressure
19 mm Hg = vapor pressure of water at 21.2 deg C
.519 gm = weight of sample
1.2 ml = volume of gas evolution

$$B = \frac{(756.4 - 19)\ (273)}{(760)\ (273 + 21.2)} = .900$$

$$\%U = \frac{(1.2)(.900)(.00608)(100)}{.519} = 1.27\ \%\ \text{metallic uranium.}$$

3.8 Waste Packaging and Shipment

Packaging and shipping requirements for burial of low level radioactive wastes are very stringent and specific in order to ensure that there will be no leakage of radioactive material during either normal transportation conditions or long term storage. The two main regulatory criteria which dictate these requirements are the Code of Federal Regulations (CFR) Title 49, "Transportation" and CFR Title 61, "Requirements for Low Level Waste Burial Sites." There may also be additional requirements imposed by a specific burial site. The Richland, Washington burial site, for example, requires solidification of all ashed material and only specific stabilization/solidification agents are approved for immobilizing liquid radioactive wastes.

The general packaging requirements dictate that the radioactive wastes must be in a dry, solid form. Thus, liquids must be absorbed, solidified or stabilized (depending upon the requirements of the disposal site).

All material must be either packaged in approved DOT Type 7A containers or shipped in exclusive use vehicles using a "strong tight container." The most commonly used Type 7A containers are 17-H 55-gallon drums and large metal boxes. The 55-gallon drums have a capacity of 7.5 cubic feet and the metal boxes are commercially available in several sizes (one of the most common has a capacity of about 100 cubic feet).

The radiation levels at the surface of each container cannot exceed 200 mrem/hr and the transport index (which is the radiation level in mrem/hr) cannot exceed 10. If shipment is done in an exclusive use vehicle, these levels can be exceeded, but the external surface of the vehicle cannot exceed 200 mrem/hr. As an indication of an extreme level that might be reached, a 55-gallon drum filled with uranium oxide (840-lbs.) has a surface reading of about 3 mrem/hr and a transport index of less than 1.

For exclusive use transportation of radioactive wastes, all containers must be marked or labeled with "Radioactive LSA", gross weight of the container, proper UN number, classification of waste (Class A, B or C), and stability (stable or unstable). If the shipment is not in an exclusive use vehicle, the yellow radioactive II sticker must be used on each drum if the radiation level at the surface of the drum is greater yhan 0.5 mrem/hr and less than 50 mrem/hr in accordance with 49 CFR 172.403.

3.9 Disposal Sites for Low Level Radioactive Wastes

There are three commercial burial sites for low level radioactive wastes in the United States. U. S. Ecology operates sites at Richland, Washington and Beatty, Nevada, and Chem-Nuclear Systems operates a site at Barnwell, South Carolina. Each of the sites may have requirements and restrictions that are unique to that site alone.

4.0 CONCLUSIONS & RECOMMENDATIONS

The following conclusions and recommendations are being made based upon the literature search and analysis in Sections 2 and 3.

4.1 Slow Burn Maximum Ashing-Complete Passivation

Using the results shown in Sections 2 and 3, we conclude that it is technically feasible to completely ash-passivate low level radioactive wastes contaminated with depleted uranium or tritium using a conventional muffle-type furnace within the established limits. The slow burn ashing-passivation-shearing-compaction approach is a low-cost volume reduction procedure. It is safe, reliable, and cost effective in handling the expected volume of low level radioactive waste generated at ARDEC in full compliance with disposal regulations. The materials that can be ashed-passivated-sheared-compacted include paper, wood, cloth (cotton), toluene, pseudocumene, HEPA filters as well as tritium and metallic uranium (depleted) low level contaminated wastes. Complete passivation of these materials should produce a volume reduction of between 20:1 to 50:1. The ashing-passivation of plastics, leather and ion exchange resins is not recommended because of the toxic products of combustion with these materials. While these materials are combustible, some type of scrubber would be necessary to remove the toxic products of combustion, and this is beyond the intended scope of using a laboratory approach for the waste reduction and disposal.

A conventional muffle furnace should be able to perform the ashing-passivation of either one cubic foot of wood/paper/cloth or 5-10 lbs. of depleted uranium wastes daily. The furnace should have a maximum temperature capability of about 2000 degrees F. The furnace design must include features to insure the proper air flow, and the off-gas must be cooled (by dilution) and passed through a HEPA filter.

As part of the ashing-passivation procedure, it may be desirable to determine the carbon content of the residue. If so, provisions for the necessary equipment to perform this measurement should be included.

It may be necessary to solidify the ash by some approved procedure prior to shipment, depending upon the specific requirements of each burial site, and shipment must be in approved containers such as 17-H 55-gallon drums.

4.2 Compaction

Compaction of low level radioactive plastics, leather, ion exchange resins and other non-ashable materials is a feasible approach for reducing the volume of these materials. Volume reductions of about 5:1 can be expected, and compactors are commercially available for use with 17-H 55-gallon drums (which become the shipping containers).

Volume reduction of HEPA filters can also be obtained by compactic , and reductions of about 5:1 (by volume) should be obtained with proper equipment. The compaction can be done directly into 85-gallon drums or rectangular metal containers that are used as shipping containers. It is also feasible to ash HEPA filters, with or without the filter frames, in order to convert any metallic uranium to uranium oxide.

The compaction systems need to be equipped with a HEPA filter in the ventilation system to prevent air borne contamination.

4.3 Flow Chart

A flow chart for the processing of low level radioactive wastes based upon the two previous sections is shown in Figure 2.

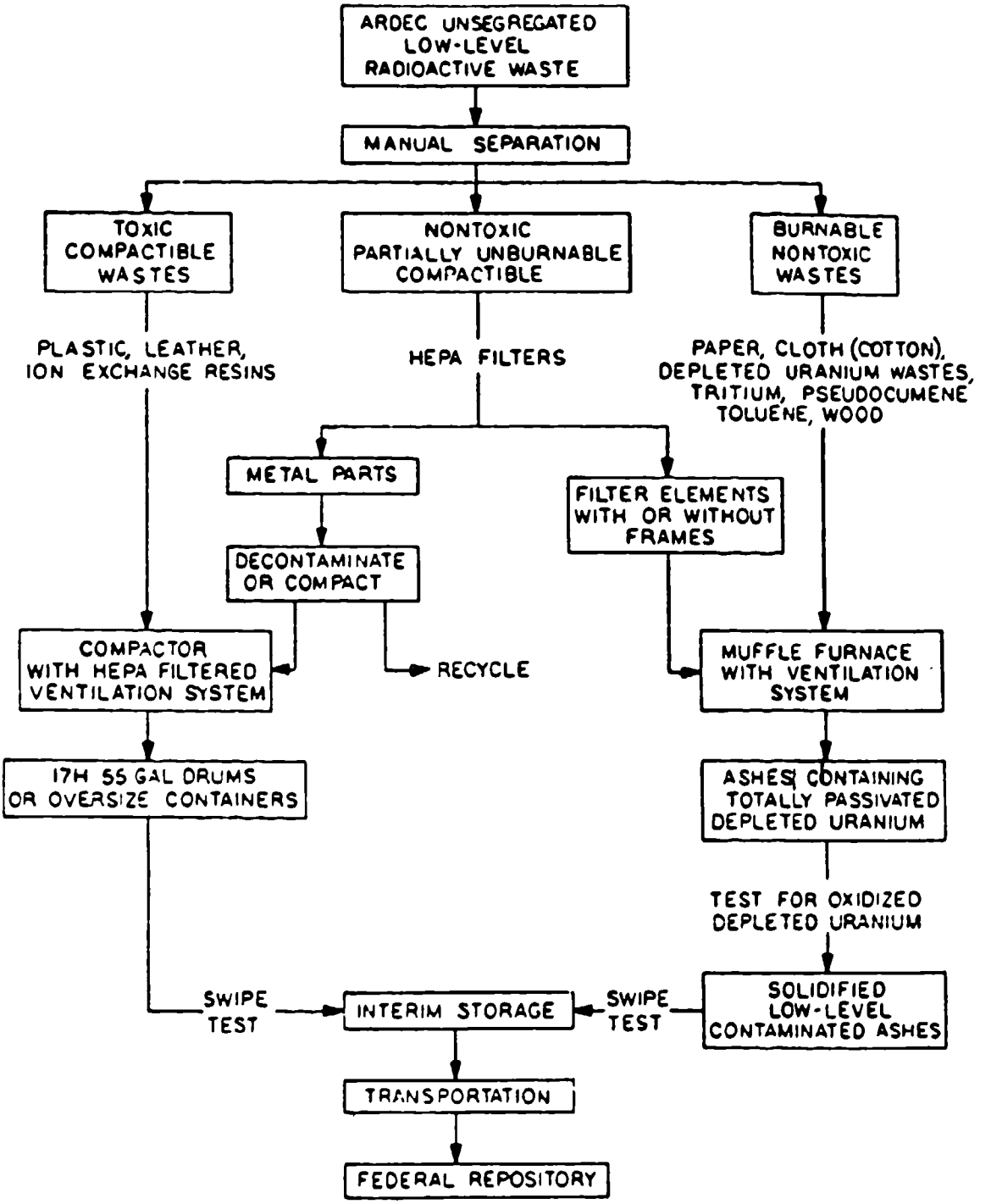

Figure 2 Flow Chart of Laboratory Low-Level Radioactive Waste Processing System.

4.4 Safety, Health Physics and Regulatory Requirements

The literature survey and the analysis indicates that the ashing of low level radioactive wastes can be done with proper safety, health physics and regulatory requirements.

It is recommended that the requirements for each potential burial site be reviewed and compared to the expected features of the ashing, storage and packaging system being developed.

It is also recommended that an ALARA Program be prepared and used as part of the disposal system.

4.5 Personnel

It is recommended that a full time health physicist be assigned to the low level radioactive waste program discussed above.

4.6 Future Efforts

It is recommended that Phase II, the furnace and system design, be undertaken using the design guidelines established in this report. The design features should also be based the description of the systems found in the literature survey. Many of these systems were developed after considerable experience, and the furnace design should consider each of the potential features.

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